Inductive Coupling Unit and Bypass Tool for Power Line Communications

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In an access-type PLC (Power Line Communications) system, medium- and low-voltage power distribution systems are used as part of a communications network. For radio frequency PLC using such distribution systems as communications paths, signal coupling and conditioning equipment are important items of hardware. The former equipment connects communications signals of a PLC modem to a distribution line, while the latter improves the communications characteristics of such distribution lines. There are bypass tools and blocking filters for conditioning tool. The function of bypass tools is to bypass communications signals around power distribution equipment, a major source of signal attenuation. The function of blocking filters is to prevent the signals from being conveyed to unnecessary power distribution systems. Signal coupling and conditioning equipment are key device for PLC business. It is necessary for us to develop considering the equipment installation and performance.

This article describes the R&D works we have conducted to develop signal coupling equipment and a bypass tool.

1. Signal Coupling Equipment

An ICU (Inductive Coupling Unit) is a piece of equipment to place communication signals in the 2 MHz- to 40-MHz range onto a distribution line and a key device in the PLC system. A current of several hundred amperes is being applied to a medium-voltage distribution line at a voltage of 6.6 to 35 kV. Since the ICU is capable of achieving signal coupling with the distribution line without contact required, it is characterized by high reliability and ease of installation on existing distribution lines.

Figure 1 shows the ICU construction. Structurally, it consists of a magnetic core with gaps plus a distribution line and modem output coil, both of which are wound around the latter core. Using the mutual inductance between the distribution and modem output lines, radio-frequency signals are coupled to the distribution line. The ratio of the magnetic core’s mutual inductance to the self-inductance is known as the core’s coupling coefficient, k. Figure 2 shows an example of the relationships between the calculated coupling coefficients and the ICU’s coupling efficiency, with self-inductance chosen at 1,500nH. The greater the coupling coefficient, the better the coupling efficiency becomes. Furthermore, the coupling coefficient has an effect on the ICU’s coupling efficiency in radio frequency regions of 10 MHz or over.

The gaps provided are to prevent the magnetic core from being saturated by the power current traversing the distribution line. The larger the length of the gaps, the less the effect of the magnetic saturation, but since the core’s coupling coefficient k also becomes smaller, the ICU’s coupling efficiency is reduced. To cope with this, we have successfully optimized the core geometries using magnetic analysis.

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*Fig. 1 ICU structure

*Fig. 2 Calculated attention with changing coupling coefficient
the characteristic impedance of the distribution line. This means that we start requiring ICUs that are matched to the characteristics of the distribution lines upon which they are to be installed. Consequently, we have been implementing ICU design through the use of magnetic field and circuit analyses.

Figure 3 shows an ICU we have developed. Figure 4 shows the characteristics of the ICU with a current of 300A. The coupling efficiency measured a maximum of -6 dB at 9 MHz in this case.

We are now downsizing and increasing efficiency of ICU by conducting the core geometries and material characteristics.

2. Bypass Tools

On power distribution systems that serve as transmission paths for access-type PLC systems, distribution devices such as transformers, distribution panelboards, voltage regulators and similar are installed. When these devices exist in communications paths, the characteristics of such paths may be adversely affected by the latter, giving rise to such phenomena as decreased communication rate or even failure. To resolve this problem, it was customary practice to install PLC repeater equipment in the vicinities of distribution devices to relay communications signals while circumventing the distribution devices. However, this strategy is costly, due to the cost of purchasing such PLC repeater equipment itself as well as the outlay for its installation and maintenance. Given these circumstances, equipment that is capable of improving the characteristics of transmission paths adversely affected by distribution equipment without the use of PLC repeater equipment, economical and easily installable has been sought after. This demand has given us impetus to start developing our own bypass tool, capable of improving the communications characteristics of distribution lines and reducing installation costs.

Figure 5 shows the installation configuration of the bypass tool. Referring to Fig. 5, a variety of distribution devices such as transformers, panelboards and voltage regulators are present. The bypass tool is installed in such a manner as to straddle this aggregate of distribution devices, consisting of high-frequency separation circuits and a cable. PLC modem derived high-frequency communications signals carried over a single distribution line are separated from commercial frequency power and coupled to the other distribution line through the cable. Thanks to this arrangement, the PLC modem's high-frequency communications signals are bypassed by the bypass tool without traversing the distribution devices.

In order to confirm the principle effect of the bypass tool, we conducted a proof-of-principle demonstration experiment at our intracompany laboratory. This experiment was conducted on a transmission path using a device that simulated a BusBar, a type of panelboard, for use as a distribution device. We performed comparative measurements of the attenuation characteristics by using and then not using the bypass tool respectively to verify the differences.

Figure 6 shows the transmission path we employed for the experiment, with the results of the attenuation characteristics recorded based on the transmission path shown in Fig. 7. Referring to the attenuation characteristics curve plotted for the case without
using the bypass tool, notches centering at around –35 dB and bottoming out at -30 dB to -50 dB are observed throughout the entire frequency spectrum. The use of the bypass tool eliminated such notches, with the overall average remaining at about -20 dB. From these findings, we were able to confirm the effect of the bypass tool in improving attenuation characteristics. We are now designing the bypass tool for real power distribution systems.

3. Conclusion

This article concerned signal coupling equipment and bypass tools, both of which are key device for a PLC business, and discussed the results of the development work conducted within our company. Our task ahead is to create a component model of the newly developed PLC equipment while, at the same time, conducting commercialization studies with particular emphasis on the ease of installation on pre-existing distribution lines. Using this model, we will build a system which would facilitate us improving the communications characteristics of power distribution systems on a computer with the help of a communications type support tool for service provision that would make pass/fail judgments.